COLLEGE OF ENGINEERING | MECHANICAL AND AEROSPACE ENGINEERING

Development of an Active Flight Envelope Warning Method for General Aviation Aircraft

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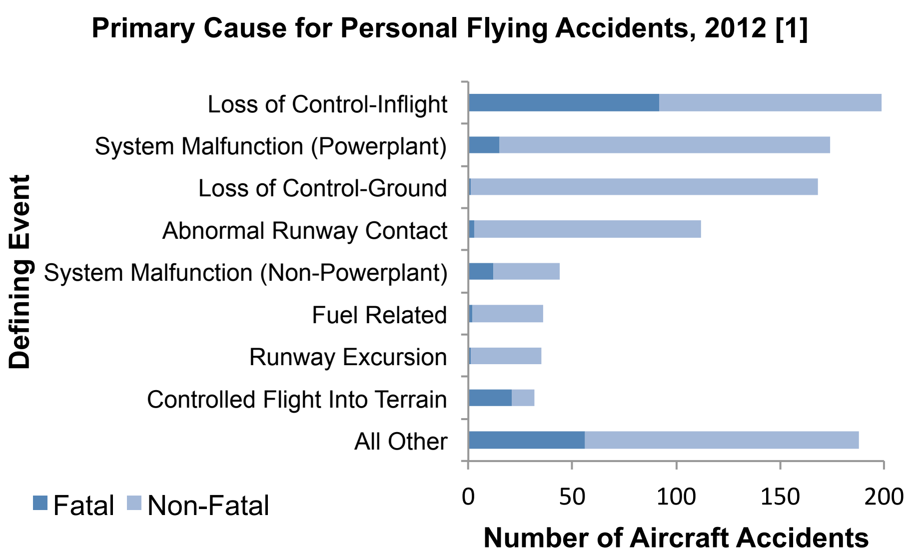
INTRODUCTION

General Aviation (GA) is any civilian flying other than scheduled passenger and cargo airlines. It accounts for nearly two-thirds of all flown hours.

Personal flying (for travel or recreation) makes up about one-third of GA flights. However, in 2012, 66.4% of all GA accidents occurred during personal flying [1]. The figure below breaks down the "defining events" of Personal Flying Accidents from a National Transportation Safety Board study.



Loss of Control accidents involve events where the pilot should have maintained or regained control of the aircraft.

Current methods to prevent Loss of Control events in GA:

- Pilot's Operating Handbooks
- Stall Warnings (5 knot margin required by FAA)
- Angle of Attack indicators
- Fly-by-wire systems

Existing prevention methods have not proved to lower the GA Personal Flying accident rate in the past decade [1]. A more effective and cost-efficient solution is needed.

AIM

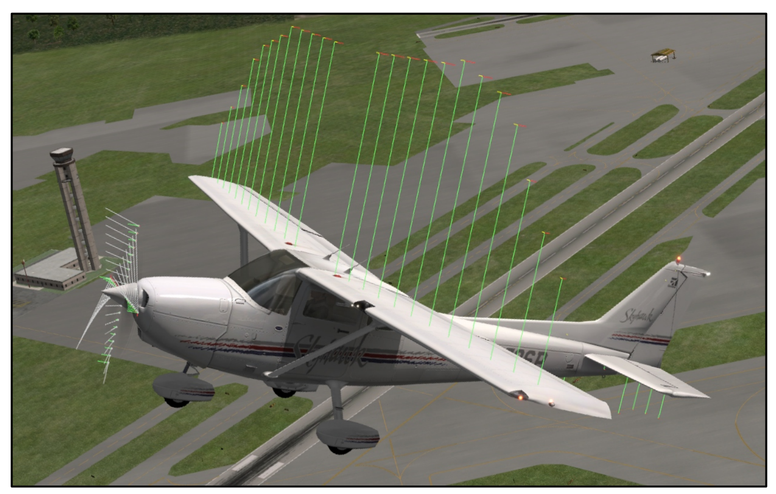
In an effort to reduce Loss of Control General Aviation accidents, this research has two primary objectives:

1) Develop a proof-of-concept for a warning system that actively considers the time a pilot has to react to a potential Loss of Control event
2) Show that the X-Plane 10 (flight simulator) flight model is physically reasonable for the development of such a warning system

METHODS

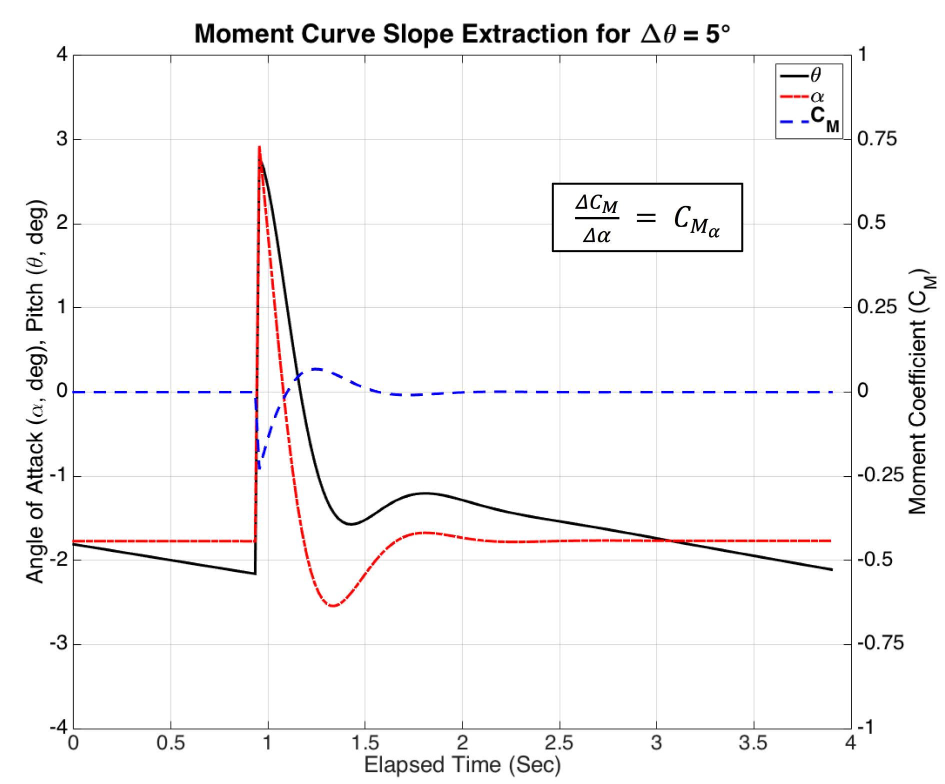
Flight Model Comparison Methods

- The Cessna 172 was selected for test and development
- Stability and performance parameters were extracted from X-Plane via "Flight Tests"
- Geometry-based empirical data calculations [3] were completed for all parameters extracted from X-Plane



A Cessna 172 flying in X-Plane 10 [2]

Stability derivatives indicate how an aircraft responds to changes in airflow around its exterior surfaces. The figure below is an example of how the aircraft in X-Plane responds to a quick positive change in pitch (upward rotation). The aircraft's time response is an indicator of its flight stability.



Typical time history method to extract data extracted from X-Plane

Warning System Methods

A software plugin was developed for X-Plane 10

- Issues live warnings to simulator's cockpit panel
- Considers aircraft's physical state and time expected until potential Loss of Control
- Constant-time warning philosophy

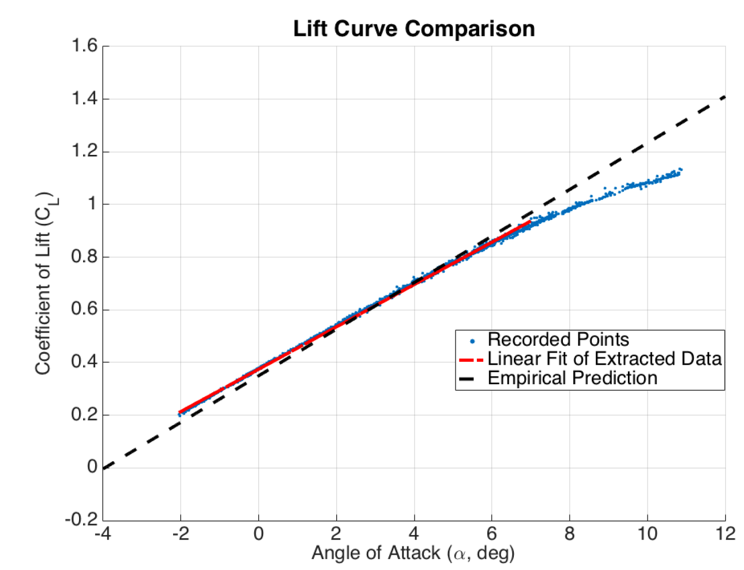
RESULTS

Flight Model Comparison Results

The Cessna 172 in X-Plane 10 compares favorably with empirical geometry-based methods of estimating stability derivatives. The table below compares some basic stability and control parameters.

Flight Model / Empirical Data Comparison

Stability Derivative	Empirical Data Calculations	X-Plane 10 Flight Test Extraction	% Difference
C_{L_α} (deg^{-1})	0.0884	0.0804	-9.0%
C_{M_α} (deg^{-1})	-0.0244	-0.0433	77%
$C_{L_{\delta E}}$ (deg^{-1})	0.0061	0.0085	39%
$C_{M_{\delta E}}$ (deg^{-1})	-0.0188	-0.0377	100%
$C_{L_{\delta f}}$ (deg^{-1})	0.0151	0.0114	-25%
$C_{M_{\delta f}}$ (deg^{-1})	-0.0039	-0.0025	-36%



Warning System Results

The software plugin warning system developed has shown increased lead on warning times when compared with the Cessna 172's built-in stall warning system. The most significant results are found with rapid approach to a stall.

Initially, false warnings were often issued with rapid control movements. They have been reduced by considering more of the aircraft's motion (accelerations) and error-checking of plugin calculations.

Modified cockpit panel used in warning system development

CONCLUSIONS

X-Plane's Flight Model

- Compares favorably with expected flight dynamics
- Allows reliable development of a loss of control warning system

Warning System

- Foundation for a constant-time warning system has been created
- Improved warnings compared to traditional systems
- Methods could be implemented into existing GA aircraft

FUTURE WORK

- Apply stall warning concepts to other flight envelope excursions (overspeed, g-load exceedance, etc.)
- Thoroughly test warning system in many flight conditions and revise to compensate for the aircraft's configuration (e.g. flaps up/down)
- A complete flight envelope warning system should be evaluated in a simulated environment to receive pilot feedback

REFERENCES

1 National Transportation Safety Board. (2014, January) Summary of US Civil Aviation Accidents for Calendar Year 2012. [Online]. http://www.ntsb.gov/investigations/data/Pages/2012%20Aviation%20Accidents%20Summary.aspx

2 Laminar Research. (2014) X-Plane 10 Global. [Online]. www.x-plane.com

3 Jan Roskam, *Methods for Estimating Stability and Control Derivatives of Conventional Subsonic Airplanes*. Lawrence, KS, United States: 1971.

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